

CLAIMS

What is claimed is:

1. An adaptive differential pulse code modulation system comprising:
 2. an encoder including:
 3. a subtractor configured for deriving a difference signal E_j , the difference signal E_j being the difference between an input signal Y_j and a predicted signal S_j , j representing a sample period;
 4. a quantizer configured for quantizing the difference signal E_j to obtain a numerical representation N_j for transmission to an encoder inverse quantizer for deriving a regenerated difference signal D_j , and to a decoder inverse quantizer coupled to the quantizer through a network for deriving the regenerated difference signal D_j ,
 5. an encoder adder configured for deriving a reconstructed input signal X_j , the reconstructed input signal X_j being the sum of the regenerated difference signal D_j and the predicted signal S_j ;
 6. an encoder whitening filter F_e configured for receiving the reconstructed input signal X_j and for generating a filtered reconstructed signal X_j^f , the
16.
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}$$
filtered reconstructed signal X_j^f being generated according to the equation:
17. X_{j-n} being a value of reconstructed input signal X_j at sample period $j-n$,
18. and;

19 n being a number of filter tap coefficients a_n^f corresponding to the
20 whitening filter F_e ;
21 an encoder predictor P_{ep} configured for receiving the reconstructed input
22 signal X_j and for generating a predicted signal S_{jp} , the predicted signal S_{jp}
23 being at least constituent to predicted signal S_j and being generated according
24 to the equation:

$$S_{jp} = a_1^j S_{i-1} + a_2^j S_{i-2} \dots a_{np}^j S_{j-np}$$

26 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
27 n_p being a number of predictor coefficients $a_{j-n_p}^i$ corresponding to the
28 predictor P_{ep} ; and

29 an encoder feedback loop configured for applying the predicted signal S_j
30 to the adder;

31 transmission means configured for transmitting the numerical
32 representation N_j from the encoder to a decoder; and
33 the decoder including:

34 the decoder inverse quantizer coupled to the quantizer through a network
35 and configured for receiving the numerical representation N_j and for deriving
36 the regenerated difference signal D_j therefrom,

37 a decoder adder configured for deriving the reconstructed input signal X_j ,
38 the reconstructed input signal X_j being the sum of the regenerated difference
39 signal D_j and the predicted signal S_j ;

40 a decoder whitening filter F_d configured for receiving the reconstructed
41 input signal X_j and for generating the filtered reconstructed signal $X_{j|}^f$, the
42 filtered reconstructed signal $X_{j|}^f$ being generated according to the equation:

43
$$X_{j|}^f = X_j - a_{j|1}^f X_{j-1} - a_{j|2}^f X_{j-2} - \dots - a_{j|n}^f X_{j-n}$$

44 X_{j-n} being a value of reconstructed signal X_j at sample period $j-n$, and
45 n being the number of filter tap coefficients $a_{j|n}^f$ corresponding to the
46 whitening filter F_d ;

47 a decoder predictor P_{dp} configured for receiving the reconstructed input
48 signal X_j and for generating a predicted signal $S_{j|p}$, the predicted signal $S_{j|p}$
49 being at least constituent to predicted signal S_j and being generated according
50 to the equation:

51
$$S_{j|p} = a_{j|1}^p S_{j-1} + a_{j|2}^p S_{j-2} + \dots + a_{j|n_p}^p S_{j-n_p}$$

52 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
53 n_p being the number of predictor coefficients $a_{j|n_p}^p$ corresponding to the
54 predictor P_{dp} ; and

55 a decoder feedback loop configured for applying the predicted signal S_j to
56 the decoder adder.

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1 2. The system of claim 1, further comprising:

2 a second encoder predictor P_{ez} configured for receiving the regenerated
3 difference signal D_j and for generating a predicted signal $S_{j|z}$;

4 a second encoder adder configured for deriving the predicted signal S_j at
5 the encoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
6 the predicted signal S_{jz} ;

7 a second decoder predictor P_{dz} configured for receiving the regenerated
8 difference signal D_j and for generating a predicted signal S_{jz} , and
9 a second decoder adder configured for deriving the predicted signal S_j at
10 the decoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
11 the predicted signal S_{jz} .

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1 3. The system of claim 1 wherein:

2 n_p is 2;

3 the predictor coefficient a_j is updated according to the equation:

$$a_i^{j+1} = a_i^j(1 - \delta_i) + g_i \cdot F_i(X_{i-1}^f, X_{i-2}^f)$$

⁵ δ_1 and g_1 being proper positive constants, and

⁶ F_1 being a nonlinear function; and

7 the predictor coefficient a_2^j is updated according to the equation:

$$a_2^{j+1} = a_2^j(1-\delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j);$$

9 δ_2 and g_2 being proper positive constants, and

10 F_2 being a nonlinear function.

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1 4. The system of claim 1 wherein:

2 n is 2;

3 the filter tap coefficient a_1^f is updated at each sample period j according to

4 the generalized equation:

5
$$a_1^{f+1} = a_1^f(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

6 δ_1 and g_1 being proper positive constants, and

7 F_1 being a nonlinear function; and

8 the filter tap coefficients a_2^f is updated at each sample period j according to

9 the generalized equation:

10
$$a_2^{f+1} = a_2^f(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^f)$$

11 δ_2 and g_2 being proper positive constants, and

12 F_2 being a nonlinear function.

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1 5. The system of claim 4 wherein:

2 the filter tap coefficient $a_1^{f,j}$ is updated according to the equation:

3
$$a_1^{f,j+1} = a_1^{f,j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f]; \text{ and}$$

4 the filter tap coefficient $a_2^{f,j}$ is updated according to the equation:

5
$$a_2^{f,j+1} = a_2^{f,j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f];$$

6 $\text{sgn}[\]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

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1 6. The system of claim 5 wherein at every other sample period j ,
2 the filter tap coefficient a^{fj+1}_2 is maintained in a range $-12288 \leq a^{fj+1}_2 \leq$
3 12288; and
4 the filter tap coefficient a^{fj+1}_1 is maintained in a range $-(15360 - a^{fj+1}_2) \leq$
5 $a^{fj+1}_1 \leq (15360 - a^{fj+1}_2)$;
6 whereby a^{fj+1}_1 is set equal to $(15360 - a^{fj+1}_2)$ when $a^{fj+1}_1 > 15360 - a^{fj+1}_2$; and
7 whereby a^{fj+1}_1 is set equal to $-(15360 - a^{fj+1}_2)$ when $a^{fj+1}_1 < -(15360 - a^{fj+1}_2)$.

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1 7. The system of claim 5, further comprising:
2 a second encoder predictor P_{ez} configured for receiving the regenerated
3 difference signal D_j and for generating a predicted signal S_{jz} ;
4 a second encoder adder configured for deriving the predicted signal S_j at
5 the encoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
6 the predicted signal S_{jz} ;
7 a second decoder predictor P_{dz} configured for receiving the regenerated
8 difference signal D_j and for generating a predicted signal S_{jz} ; and
9 a second decoder adder configured for deriving the predicted signal S_j at
10 the decoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
11 the predicted signal S_{jz} .

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1 8. The system of claim 1 wherein at every other sample period j , the predictor
2 coefficient a_{jnp} corresponding to the predictors P_{ep} and P_{dp} is maintained
3 unchanged.

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1 9. The system of claim 8, such that if for even j:

$a_i^{j+1} = a_i^j$, and

$$a_2^{j+1} = a_2^j,$$

4 then for odd j:

$$a_i^{j+1} = a_i^{j-1} \left(1 - \left(\frac{127.5}{32768} \right) \right) + 191.25 * \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-2}^f] + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

$$a_2^{j+1} = a_2^{j-1} \left(1 - \left(\frac{510}{32768} \right) \right) - \left(\frac{1016}{32768} \right) \lim[a_1^{j-1}] \operatorname{sgn}[X_{j-1}^f] \operatorname{sgn}[X_{j-2}^f] + 127 * \operatorname{sgn}[X_{j-1}^f] \operatorname{sgn}[X_{j-3}^f] \\ - \left(\frac{1}{32} \right) \lim[a_1^{j-1}] \operatorname{sgn}[X_j^f] \operatorname{sgn}[X_{j-1}^f] + 128 * \operatorname{sgn}[X_j^f] \operatorname{sgn}[X_{j-2}^f],$$

7 sgn[] being a sign function that returns a value of 1 for a nonnegative
8 argument and a value of -1 for a negative argument, and

$$9 \quad \lim[a_1^{j-1}] = a_1^{j-1} \text{ for } -8192 \leq a_1^{j-1} \leq 8191,$$

$$10 \quad \lim[a_1^{j-1}] = -8192 \text{ for } a_1^{j-1} < -8191, \text{ and}$$

$$11 \quad \lim[a_1^{j-1}] = 8192 \text{ for } a_1^{j-1} > 8191.$$

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1 10. An encoder for encoding digital audio signals, comprising:

2 a subtractor configured for deriving a difference signal E_j , the difference

3 signal E_j being the difference between an input signal Y_j and a predicted

4 signal S_j , j representing a sample period;

5 a quantizer configured for quantizing the difference signal E_j to obtain a

6 numerical representation N_j for transmission to an encoder inverse quantizer

7 for deriving a regenerated difference signal D_j , and to a decoder inverse

8 quantizer coupled to the quantizer for deriving the regenerated difference

9 signal D_j ;

10 an adder configured for deriving a reconstructed input signal X_j , the

11 reconstructed input signal X_j being the sum of the regenerated difference

12 signal D_j and the predicted signal S_j ;

13 a whitening filter configured for receiving the reconstructed input signal

14 X_j and for generating a filtered reconstructed signal X_j^f , the filtered

15 reconstructed signal X_j^f being generated according to the equation:

16
$$X_j^f = X_j - a_{j-1}^f X_{j-1} - a_{j-2}^f X_{j-2} - \dots - a_{j-n}^f X_{j-n}$$

17 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

18 and

19 n being a number of filter tap coefficients a_{j-n}^f corresponding to the

20 whitening filter;

21 a predictor configured for receiving the reconstructed input signal X_j and

22 for generating a predicted signal S_{jp} , the predicted signal S_{jp} being at least

23 constituent to predicted signal S_j and being generated according to the
24 equation:

25
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

26 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
27 n_p being a number of predictor coefficients a_{jn_p} corresponding to the
28 predictor; and

29 a feedback loop configured for applying the predicted signal S_j to the
30 adder.

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1 11. The system of claim 10, the encoder further comprising:
2 a second predictor configured for receiving the regenerated difference
3 signal D_j and for generating a predicted signal S_{jz} , the predicted signal S_{jz} being
4 at least constituent to predicted signal S_j ; and
5 a second adder configured for deriving the predicted signal S_j , the
6 predicted signal S_j being the sum of the predicted signal S_{jp} and the predicted
7 signal S_{jz} .

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1 12. The system of claim 10 wherein:
2 n is 2;
3 the filter tap coefficient a_1^f is updated at each sample period j according to
4 the generalized equation:

5 $a_1^{f+1} = a_1^f(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$

6 δ_1 and g_1 being proper positive constants, and

7 F_1 being a nonlinear function;

8 the filter tap coefficients a_2^f is updated at each sample period j according

9 to the generalized equation:

10 $a_2^{f+1} = a_2^f(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^f)$

11 δ_2 and g_2 being proper positive constants, and

12 F_2 being a nonlinear function.

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1 13. The system of claim 12 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

3
$$a_1^{f+1} = a_1^{f,j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

5
$$a_2^{f+1} = a_2^{f,j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f],$$

6 $\text{sgn}[]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

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1 14. The system of claim 13 wherein at every other sample period j ,

2 the filter tap coefficient $a_2^{f+1,2}$ is maintained in a range $-12288 \leq a_2^{f+1,2} \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$
5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;
6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and
7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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1 15. The system of claim 10 wherein at every other sample period j , the predictor
2 coefficient a_{np}^j corresponding to the predictor is maintained unchanged.

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1 16. The system of claim 10, wherein the encoder is constituent to or coupled to a
2 videoconferencing device or application.

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17. A decoder for decoding digital audio signals encoded by a properly
associated encoder, comprising:
an inverse quantizer coupled to the encoder and configured for receiving
a numerical representation N_j and for deriving a regenerated difference signal
 D_j therefrom, the numerical representation N_j being a quantized
representation of a difference signal E_j , the difference signal E_j being the
difference between an input signal Y_j and a predicted signal S_j , j representing
a sample period;
an adder configured for deriving a reconstructed input signal X_j , the
reconstructed input signal X_j being the sum of the regenerated difference
signal D_j and the predicted signal S_j ;
a whitening filter configured for receiving the reconstructed input signal
 X_j and for generating a filtered reconstructed signal X_j^f , the filtered
reconstructed signal X_j^f being generated according to the equation:
$$X_j^f = X_j - a_{j-1}^f X_{j-1} - a_{j-2}^f X_{j-2} - \dots - a_{j-n}^f X_{j-n}$$

 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
and
 n being a number of filter tap coefficients a_{j-n}^f corresponding to the
whitening filter;
a predictor configured for receiving the reconstructed input signal X_j and
for generating a predicted signal S_{jp} , the predicted signal S_{jp} being at least

22 constituent to predicted signal S_j and being generated according to the
23 equation:

24
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

25 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
26 n_p being a number of predictor coefficients a_{jn_p} corresponding to the
27 predictor; and

28 a feedback loop configured for applying the predicted signal S_j to the
29 adder.

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1 18. The system of claim 17, the decoder further comprising:
2 a second predictor configured for receiving the regenerated difference
3 signal D_j and for generating a predicted signal S_{jz} , the predicted signal S_{jz} being
4 at least constituent to predicted signal S_j ; and
5 a second adder configured for deriving the predicted signal S_j , the
6 predicted signal S_j being the sum of the predicted signal S_{jp} and the predicted
7 signal S_{jz} .

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1 19. The system of claim 17 wherein:
2 n is 2;
3 the filter tap coefficient a_j^f is updated at each sample period j according to
4 the generalized equation:

5 $a_1^{f+1} = a_1^f(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$

6 δ_1 and g_1 being proper positive constants, and

7 F_1 being a nonlinear function;

8 the filter tap coefficients a_2^f is updated at each sample period j according

9 to the generalized equation:

10 $a_2^{f+1} = a_2^f(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^f)$

11 δ_2 and g_2 being proper positive constants, and;

12 F_2 being a nonlinear function.

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1 20. The system of claim 19 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

3
$$a_1^{f+j+1} = a_1^{f+j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

5
$$a_2^{f+j+1} = a_2^{f+j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f+j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

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1 21. The system of claim 20 wherein at every other sample period j ,

2 the filter tap coefficient $a_1^{f+1} a_2^f$ is maintained in a range $-12288 \leq a_1^{f+1} a_2^f \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$
5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;
6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and
7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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1 22. The system of claim 17 wherein at every other sample period j , the predictor
2 coefficient a_{np}^j corresponding to the predictor is maintained unchanged.

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1 23. The system of claim 17, wherein the decoder is constituent to or coupled to a
2 videoconferencing device or application.

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1 24. A method for encoding and decoding digital audio signals, comprising the
2 steps of:

3 deriving a difference signal E_j at an encoder, the difference signal E_j being
4 the difference between an input signal Y_j and a predicted signal S_j , j
5 representing a sample period;

6 quantizing the difference signal E_j to obtain a numerical representation N_j
7 for transmitting to an encoder inverse quantizer for deriving a regenerated
8 difference signal D_j , and to a decoder inverse quantizer coupled to the
9 quantizer through a network for deriving the regenerated difference signal
10 D_j ;

11 deriving a reconstructed input signal X_j at a first adder, the reconstructed
12 input signal X_j being the sum of the regenerated difference signal D_j and the
13 predicted signal S_j ;

14 receiving the reconstructed input signal X_j at a whitening filter F_e ;
15 generating a filtered reconstructed signal X_j^f by the whitening filter F_e , the
16 filtered reconstructed signal X_j^f being generated according to the equation:

$$X_j^f = X_j - a_{j-1}^f X_{j-1} - a_{j-2}^f X_{j-2} - \dots - a_{j-n}^f X_{j-n}$$

17 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
18 and

19 n being a number of filter tap coefficients a_{j-n}^f corresponding to the
20 whitening filter F_e ;

21 receiving the reconstructed input signal X_j at a predictor P_{ep} ;

23 generating a predicted signal S_{jp} by the predictor P_{ep} , the predicted signal
24 S_{jp} being at least constituent to predicted signal S_j and being generated
25 according to the equation:

26
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

27 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
28 n_p being a number of predictor coefficients a_{jn_p} corresponding to the
29 predictor P_{ep} ;

30 applying the predicted signal S_j to the first adder to provide feedback;

31 receiving the numerical representation N_j at a decoder;

32 deriving the regenerated difference signal D_j from the numerical
33 representation N_j ,

34 deriving the reconstructed input signal X_j at a second adder, the
35 reconstructed input signal X_j being the sum of the regenerated difference
36 signal D_j and the predicted signal S_j ;

37 receiving the reconstructed input signal X_j at a whitening filter F_d ;

38 generating a filtered reconstructed signal $X_{j'}^f$ by the whitening filter F_d , the
39 filtered reconstructed signal $X_{j'}^f$ being generated according to the equation:

40
$$X_{j'}^f = X_j - a_{f1} X_{j-1} - a_{f2} X_{j-2} - \dots - a_{fn} X_{j-n}$$

41 X_{j-n} being a value of filtered reconstructed signal $X_{j'}^f$ at sample period $j-n$;

42 n being a number of filter tap coefficients a_{fn} corresponding to the
43 whitening filter F_d ;

44 receiving the reconstructed input signal X_j at a predictor P_{dp} ;

45 generating a predicted signal S_{jp} by the predictor P_{dp} , the predicted signal
46 S_{jp} being at least constituent to predicted signal S_j and being generated
47 according to the equation:
48
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

49 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
50 n_p being a number of predictor coefficients a_{jn_p} corresponding to the
51 predictor P_{dp} ; and
52 applying the predicted signal S_j to the second adder to provide feedback.

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1 25. The method of claim 24, further comprising the steps of:
2 receiving the regenerated difference signal D_j at a predictor P_{ez} at the
3 encoder;
4 generating a predicted signal S_{jz} by the predictor P_{ez} ;
5 deriving the predicted signal S_j at the encoder, the predicted signal S_j
6 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} ;
7 receiving the regenerated difference signal D_j at a predictor P_{dz} at the
8 decoder;
9 generating the predicted signal S_{jz} by the predictor P_{dz} ; and
10 deriving the predicted signal S_j at the decoder, the predicted signal S_j
11 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} .

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1 26. The method of claim 24 wherein n_p is 2, further comprising the steps of:

2 updating the predictor coefficient a_1^j according to the equation:

3
$$a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

4 δ_1 and g_1 being proper positive constants, and

5 F_1 being a nonlinear function; and

6 updating the predictor coefficient a_2^j according to the equation:

7
$$a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8 δ_2 and g_2 being proper positive constants, and;

9 F_2 being a nonlinear function.

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1 27. The method of claim 24 wherein n is 2, further comprising the steps of:

2 updating the filter tap coefficient a_1^f at each sample period j according to

3 the generalized equation:

4
$$a_1^{f+1} = a_1^f(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

5 δ_1 and g_1 being proper positive constants, and

6 F_1 being a nonlinear function; and

7 updating the filter tap coefficients a_2^f at each sample period j according to

8 the generalized equation:

9
$$a_2^{f+1} = a_2^f(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^f)$$

10 δ_2 and g_2 being proper positive constants, and

11 F_2 being a nonlinear function.

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1 28. The method of claim 27 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

3
$$a_1^{f,j+1} = a_1^{f,j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

5
$$a_2^{f,j+1} = a_2^{f,j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[]$ being a sign function that returns a value of 1 for a nonnegative argument and a value of -1 for a negative argument.

1

1 29. The method of claim 28 wherein at every other sample period j ,

2 the filter tap coefficient a^{f+1}_2 is maintained in a range $-12288 \leq a^{f+1}_2 \leq 12288$; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;

6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and

7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

1

1 30. The method of claim 28, further comprising the steps of:

2 receiving the regenerated difference signal D_j at a predictor P_{ez} at the encoder;

4 generating a predicted signal S_{jz} by the predictor P_{dz} ;

- 5 deriving the predicted signal S_j at the encoder, the predicted signal S_j
- 6 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} ;
- 7 receiving the regenerated difference signal D_j at a predictor P_{dz} at the
- 8 decoder;
- 9 generating the predicted signal S_{jz} by the predictor P_{dz} ; and
- 10 deriving the predicted signal S_j at the decoder, the predicted signal S_j
- 11 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} .

$$a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_i^f, X_{i-1}^f, X_{i-2}^f)$$

4 δ_1 and g_1 being proper positive constants, and

5 F₁ being a nonlinear function; and

6 updating the predictor coefficient a_2^j according to the equation:

$$a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8 δ_2 and g_2 being proper positive constants, and;

9 F₂ being a nonlinear function:

1

1

1 32. A method for adapting coefficients in a two pole predictor in an adaptive
2 differential pulse code modulation system, comprising the steps of:

3 generating a filtered reconstructed signal X_j^f by a whitening filter F_e , the
4 filtered reconstructed signal X_j^f being generated according to the equation:

$$5 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}$$

6 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
7 and

8 n being a number of filter tap coefficients a_n^f corresponding to the
9 whitening filter F_e ;

10 updating a predictor coefficient a_1^j according to the equation:

$$11 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

12 δ_1 and g_1 being proper positive constants, and
13 F_1 being a nonlinear function; and

14 updating a predictor coefficient a_2^j according to the equation:

$$15 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

16 δ_2 and g_2 being proper positive constants, and
17 F_2 being a nonlinear function.

1

1 33. The method of claim 32, further comprising the steps of:
2 updating the filter tap coefficient a_1^f at each sample period j according to
3 the generalized equation:

4 $a_1^{f+1} = a_1^f(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$

5 δ_1 and g_1 being proper positive constants, and

6 F_1 being a nonlinear function; and

7 updating the filter tap coefficients a_2^f at each sample period j according to

8 the generalized equation:

9 $a_2^{f+1} = a_2^f(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^f)$

10 δ_2 and g_2 being proper positive constants, and

11 F_2 being a nonlinear function.

1

1 34. The method of claim 32 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

3
$$a_1^{f+j+1} = a_1^{f+j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

5
$$a_2^{f+j+1} = a_2^{f+j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f+j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[\cdot]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

1

1 35. The method of claim 34 wherein at every other sample period j ,

2 the filter tap coefficient $a_1^{f+1}_2$ is maintained in a range $-12288 \leq a_1^{f+1}_2 \leq$

3 12288; and

4 the filter tap coefficient a^{fj+1}_1 is maintained in a range $-(15360 - a^{fj+1}_2) \leq$

5 $a^{fj+1}_1 \leq (15360 - a^{fj+1}_2)$;

6 whereby a^{fj+1}_1 is set equal to $(15360 - a^{fj+1}_2)$ when $a^{fj+1}_1 > 15360 - a^{fj+1}_2$; and

7 whereby a^{fj+1}_1 is set equal to $-(15360 - a^{fj+1}_2)$ when $a^{fj+1}_1 < -(15360 - a^{fj+1}_2)$.

1

1

1 ✓³⁶. A machine readable medium embodying instructions executable by a
2 machine to perform a method for adapting coefficients in a two pole predictor in
3 an adaptive differential pulse code modulation system, the method steps
4 comprising:

5 generating a filtered reconstructed signal X_j^f by a whitening filter, the
6 filtered reconstructed signal X_j^f being generated according to the equation:

7
$$X_j^f = X_j - a_{j-1}^f X_{j-1} - a_{j-2}^f X_{j-2} - \dots - a_{j-n}^f X_{j-n}$$

8 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

9 and

10 n being a number of filter tap coefficients a_n^f corresponding to the
11 whitening filter;

12 updating a predictor coefficient a_1^j according to the equation:

13
$$a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

14 δ_1 and g_1 being proper positive constants, and

15 F_1 being a nonlinear function; and

16 updating a predictor coefficient a_2^j according to the equation:

17
$$a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

18 δ_2 and g_2 being proper positive constants, and

19 F_2 being a nonlinear function.

1

1

1 37. A digital circuit embodying instructions to perform a method for adapting
2 coefficients in a two pole predictor in an adaptive differential pulse code
3 modulation system, the method steps comprising:

4 generating a filtered reconstructed signal X_j^f by a whitening filter, the
5 filtered reconstructed signal X_j^f being generated according to the equation:

6
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}$$

7 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

8 and

9 n being a number of filter tap coefficients a_n^f corresponding to the
10 whitening filter;

11 updating a predictor coefficient a_1^j according to the equation:

12
$$a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

13 δ_1 and g_1 being proper positive constants, and

14 F_1 being a nonlinear function; and

15 updating a predictor coefficient a_2^j according to the equation:

16
$$a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

17 δ_2 and g_2 being proper positive constants, and

18 F_2 being a nonlinear function.

1

1

1 38. An adaptive differential pulse code modulation system comprising:

2 at a first instance:

3 means for deriving a difference signal E_j , the difference signal E_j being the

4 difference between an input signal Y_j and a predicted signal S_j , j representing a

5 sample period;

6 means for quantizing the difference signal E_j to obtain a numerical

7 representation N_j ;

8 means for deriving a regenerated difference signal D_j based on the

9 numerical representation N_j ,

10 means for transmitting the numerical representation N_j to an inverse

11 quantizing means coupled to the quantizing means through a network;

12 means for deriving a reconstructed input signal X_j , the reconstructed input

13 signal X_j being the sum of the regenerated difference signal D_j and the

14 predicted signal S_j ;

15 means for generating a filtered reconstructed signal $X_{j,n}^f$, the filtered

16 reconstructed signal $X_{j,n}^f$ being generated according to the equation:

17
$$X_{j,n}^f = X_j - a_{j,1} X_{j-1} - a_{j,2} X_{j-2} - \dots - a_{j,n} X_{j-n}$$

18 X_{j-n}^f being a value of filtered reconstructed signal $X_{j,n}^f$ at sample period $j-n$,

19 and

20 n being a number of coefficients $a_{j,n}^f$ corresponding to the means for

21 generating a filtered reconstructed signal;

22 means for generating a predicted signal S_{jp} , the predicted signal S_{jp} being
23 at least constituent to predicted signal S_j and being generated according to the
24 equation:

25
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

26 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and

27 n_p being a number of predictor coefficients a_{jn_p} corresponding to the
28 means for generating a predicted signal; and

29 feedback means for applying the predicted signal S_j to the means for
30 deriving a reconstructed input signal X_j ;

31 at a second instance:

32 the inverse quantizing means for deriving the regenerated difference
33 signal D_j from the numerical representation N_j ;

34 second means for deriving a reconstructed input signal X_j , the
35 reconstructed input signal X_j being the sum of the regenerated difference
36 signal D_j and the predicted signal S_j ;

37 second means for generating a filtered reconstructed signal $X_f^f_j$, the filtered
38 reconstructed signal $X_f^f_j$ being generated according to the equation:

39
$$X_f^f_j = X_j - a_{f1} X_{j-1} - a_{f2} X_{j-2} - \dots - a_{fn} X_{j-n}$$

40 X_{j-n} being a value of filtered reconstructed signal $X_f^f_j$ at sample period $j-n$,
41 and

42 n being a number of coefficients a_{fn} corresponding to the second means
43 for generating a filtered reconstructed signal;

44 second means for generating a predicted signal S_{jp} , the predicted signal S_{jp}
45 being at least constituent to predicted signal S_j and being generated according
46 to the equation:

47
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jn_p} S_{j-n_p}$$

48 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and

49 n_p being a number of coefficients a_{jn_p} corresponding to the means for
50 generating a predicted signal; and

51 feedback means for applying the predicted signal S_j to the means for
52 deriving a reconstructed input signal X_j .